National Energy Technology Laboratory

Advanced Cooling Strategies/ Technologies Conference

NETL Water Program Overview

June 1, 2005

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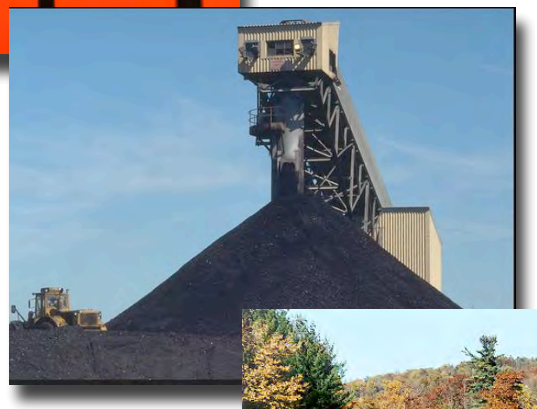
US Department of Energy/National Energy Technology Laboratory

Three Things Power Plants Require

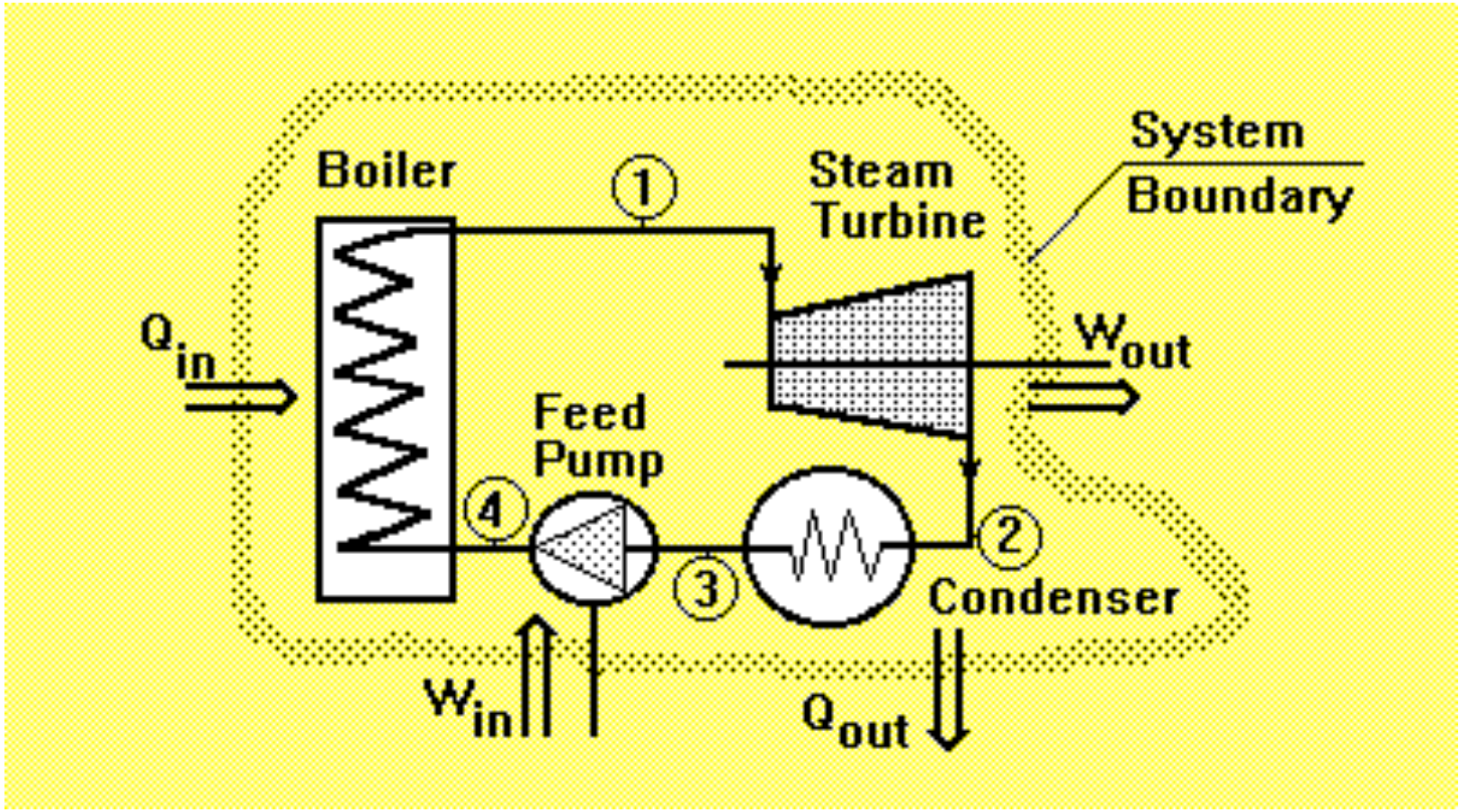
1) Access to transmission lines



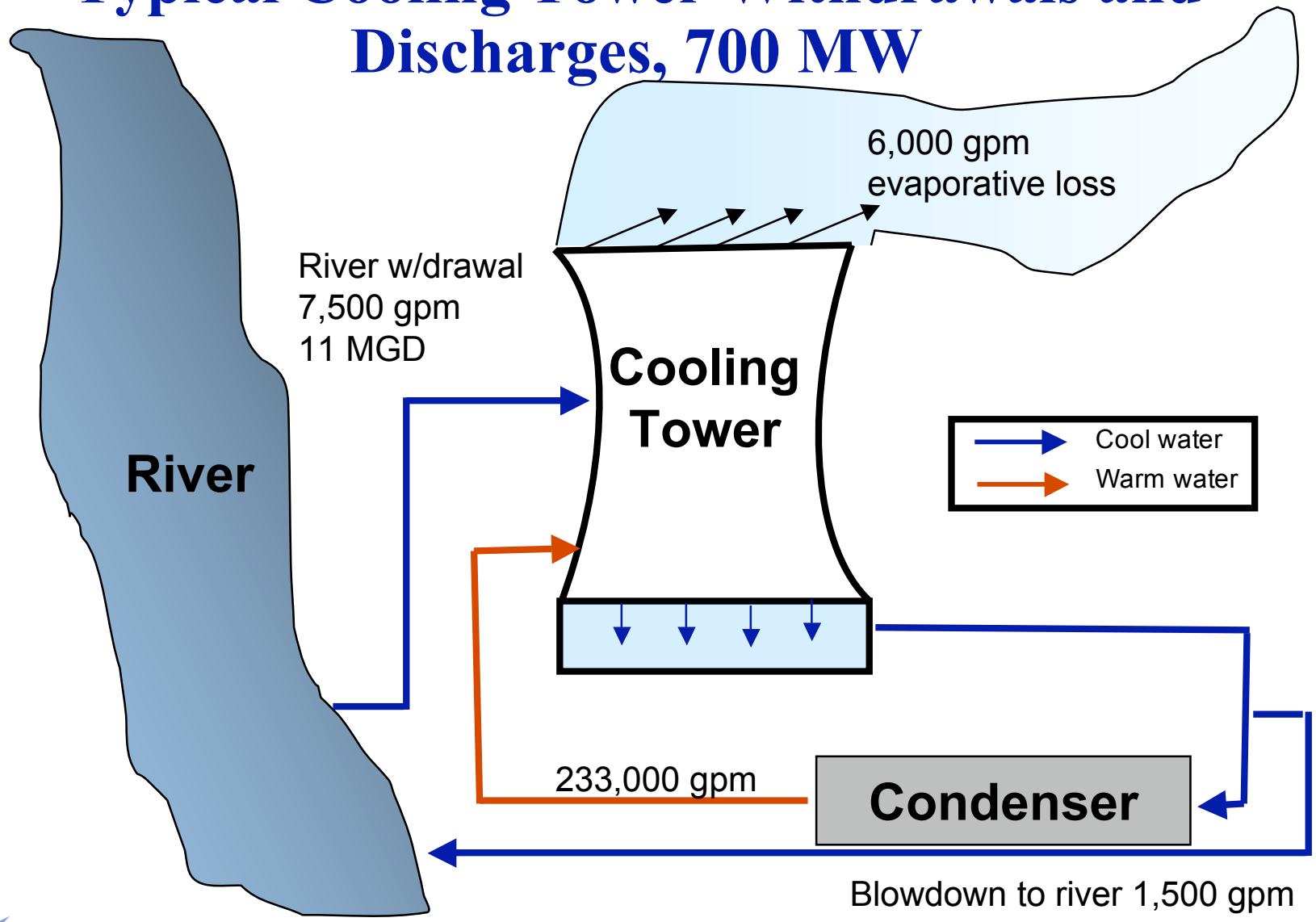
2) Available fuel, e.g., coal or natural gas

3) Water

Rankine Cycle

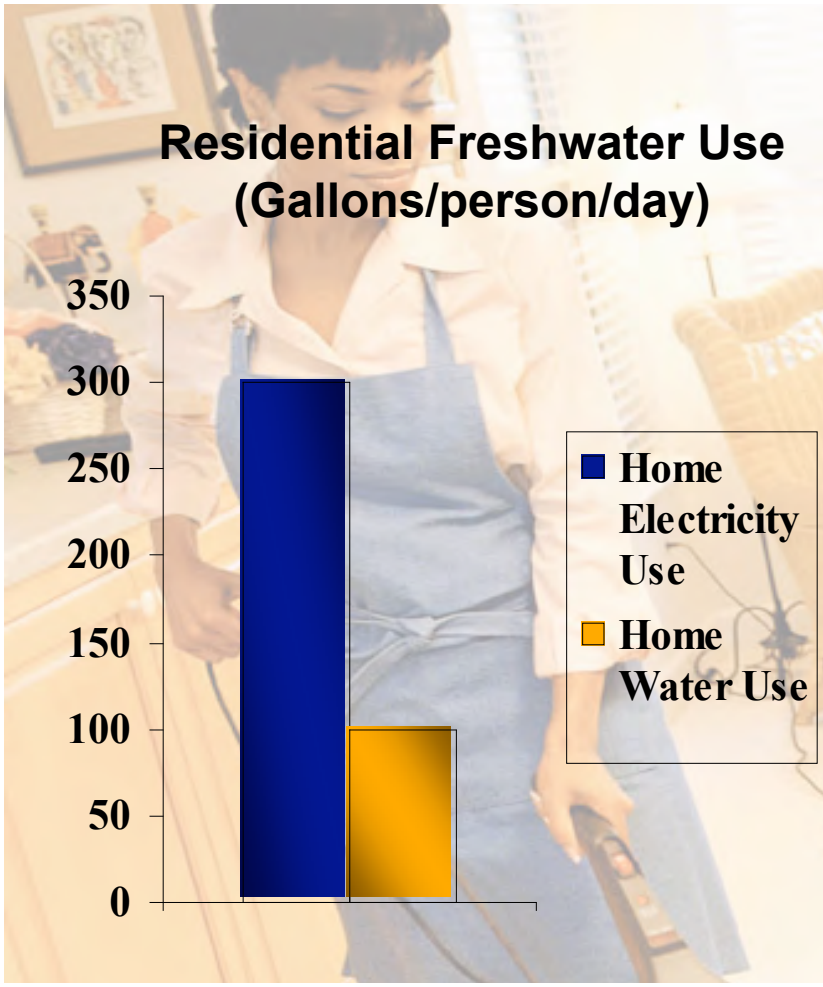


Typical Cooling Tower Withdrawals and Discharges, 700 MW



Ref. Discussion with FirstEnergy plant personnel.

Water and Electricity Are Inextricably Linked

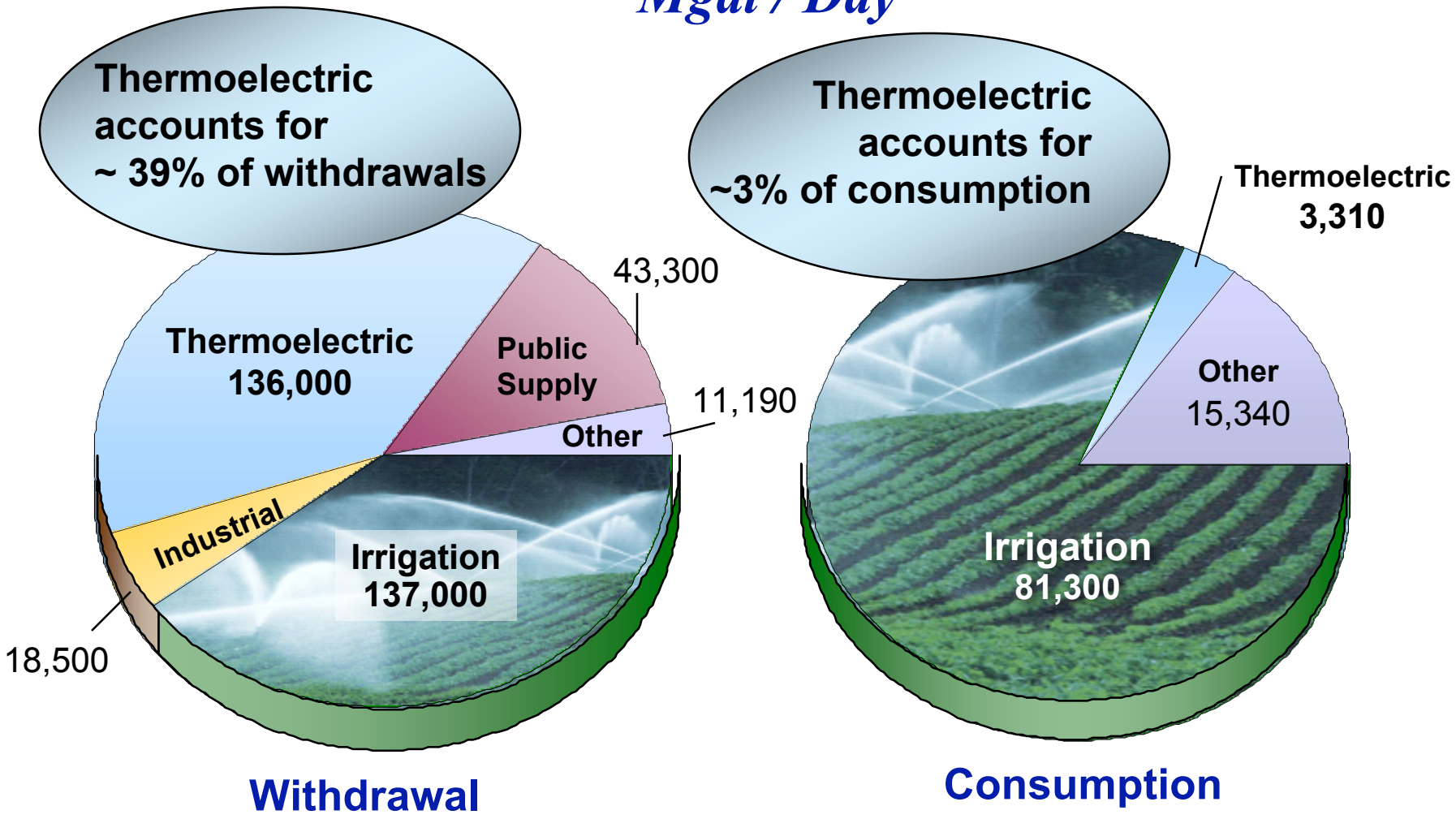


- Each kilowatt-hour of electricity requires on average about 25 gallons of water to produce.
  Once through: 30-40 gallons
  Cooling towers:
  1 gallon evaporation
- Therefore, we use almost 3 times as much water turning on lights and running appliances as we do taking showers and watering lawns.

Ref. DOE/NETL Draft Final Report, "Water-Energy RD&D Scoping Report, September 2003"

Freshwater Withdrawals and Consumption

Mgal / Day



Sources: "Estimated Use of Water in the United States in 1995," USGS Circular 1200, 1998
"Estimated Use of Water in the United States in 2000," USGS Circular 1268, March 2004

Clean Water Act 316(b)

- ….. the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.
- Entrainment, Impingement, Thermal
- Consent Decree, October 1995

Adverse Environmental Impacts

- **Steam Electric Plants (NPDES permits)**
  - 3-4 billion larvae/post larvae per year
  - 23 tons fish/shellfish per year
  - 1 million fish/ 3 week study
- **Hudson River Study**
  - Entrainment mortality
  - 6 species, 4-79% reduction
- **Cape Fear Estuarine System Modeling**
  - 15-35% population reduction

Adverse Environmental Impacts- More Recent

- **Brayton Point (Mt Hope Bay, RI)**
  - Unit 4 closed cycle to once through in 1985, 45% more flow, finfish decline 87%, 5 billion tautog eggs, 0.9 billion windowpane eggs, 0. 9 billion winter flounder larvae
- **San Onofre Nuclear Generating Station (S. Calif.)**
  - 60% reduction in kelp (turbidity)
  - 70% fish decline (impact area), 17% (water column)
  - Entrainment 16-45 tons/year
    - 350,000 juvenile white croaker killed
    - 33,000 adults killed
    - 3.5 tons killed

Cooling Water Intake Structures
316(b) Regulations

- Phase I – New Facilities
- Phase II – Large Existing Electric Generating Plants
- Phase III – Existing Facilities-Small and Non Power Producers

- Reduce impingement mortality by 80-95%
- Reduce entrainment by 60-90 %
- Through-screen velocity of 0.5 feet per second (ft/s) or less

316(b) Phase II Regulations

- Final rule February 16, 2004
- Withdraw > 50 million gallons/day
- 550 Facilities
- 220 Billion gallons per day
- $400 Million/year cost to implement
- $80 Million/year benefit
- Save 200 million pounds aquatic organisms
- Restoration measures allowed

In the News -- Water-Related Impacts on Power Plants

- **Feds Order Susquehanna Power Plants and Others to Stop Killing Fish**
  - *Lancaster (PA) New Era,* February 24, 2005
- **Nevada Residents Wary of Sempra Water Rights Purchases**
  - *Greenwire*, February 22, 2005
- **Enviros Say Wisconsin Energy Plant Discharges Could Harm Fish**
  - *Greenwire,* February 17, 2005
- **Missouri River Power Plants Potentially Affected by Varying River Levels**
  - *Platts Energy Bulletin,* February 15, 2005
- **Nevada Power Plant Threatens Honey Lake Valley Water**
  - *Lasson County (NV) News,* January 25, 2005

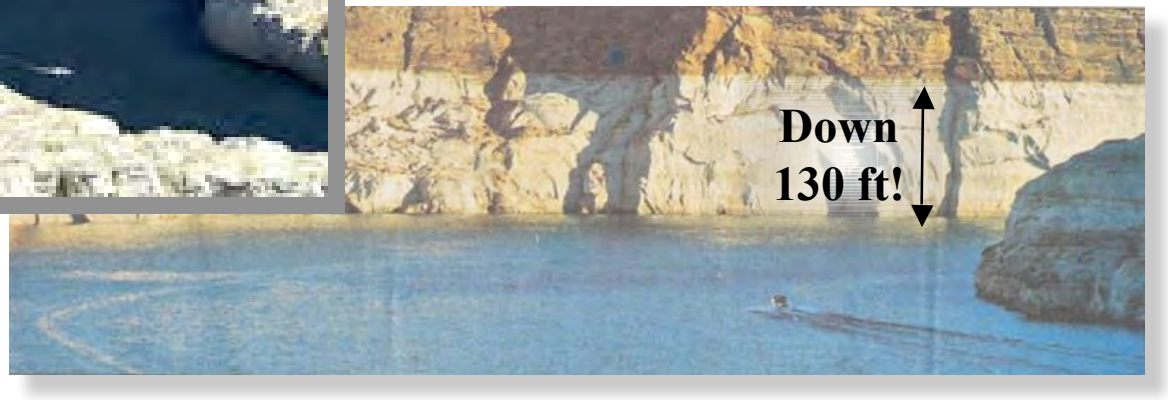
Drought Could Significantly Impact Missouri River Power Plants

South Dakota Gov. Mike Rounds suggests current drought could be particularly bad for power plants that use Missouri River water for cooling

Source: www.maps.platts.com

Ref: www.billingsgazette.com

Western Drought Continuing



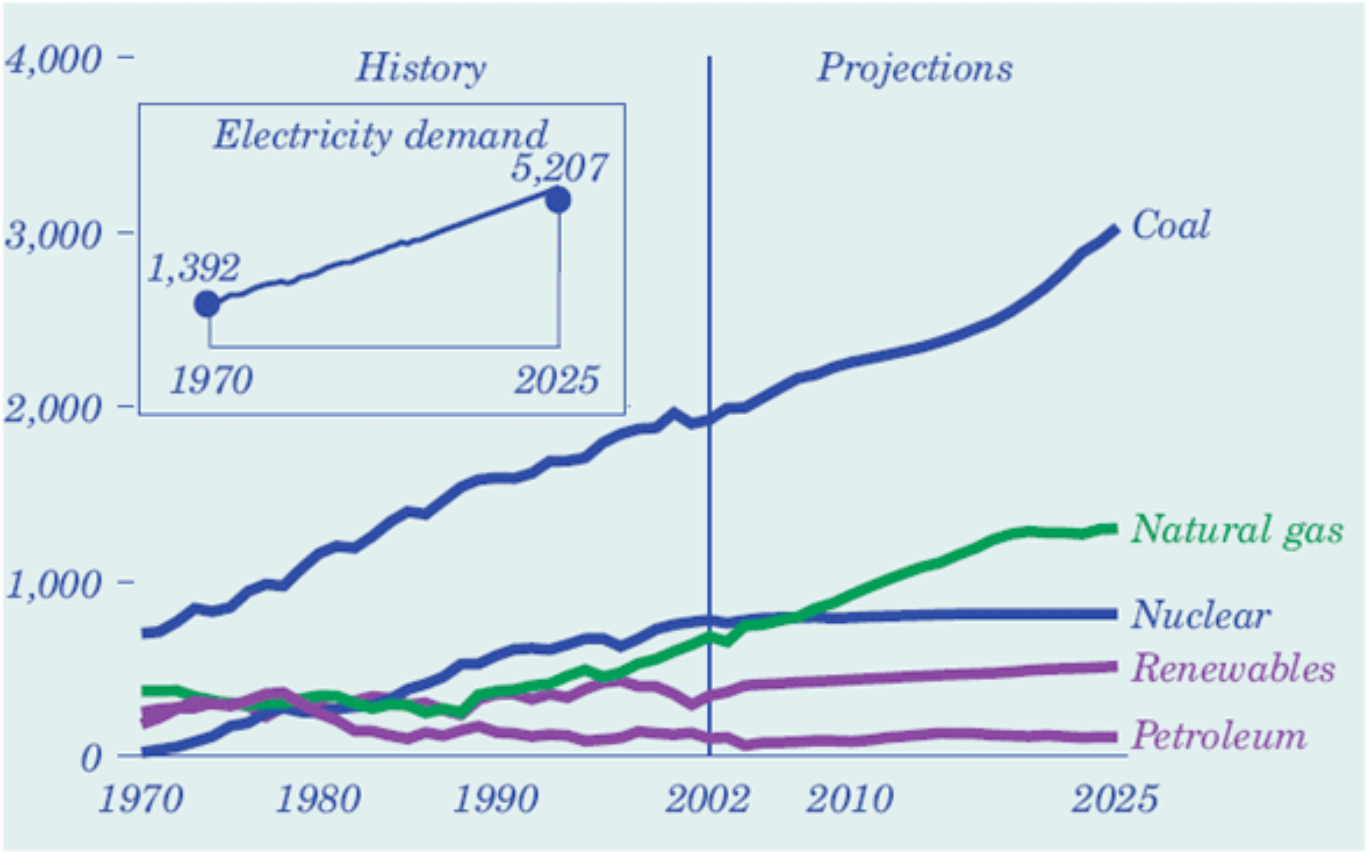
Lake Powell

- **5 years of drought**
- **Less than ½ full**

Source: USA Today 9/30/04

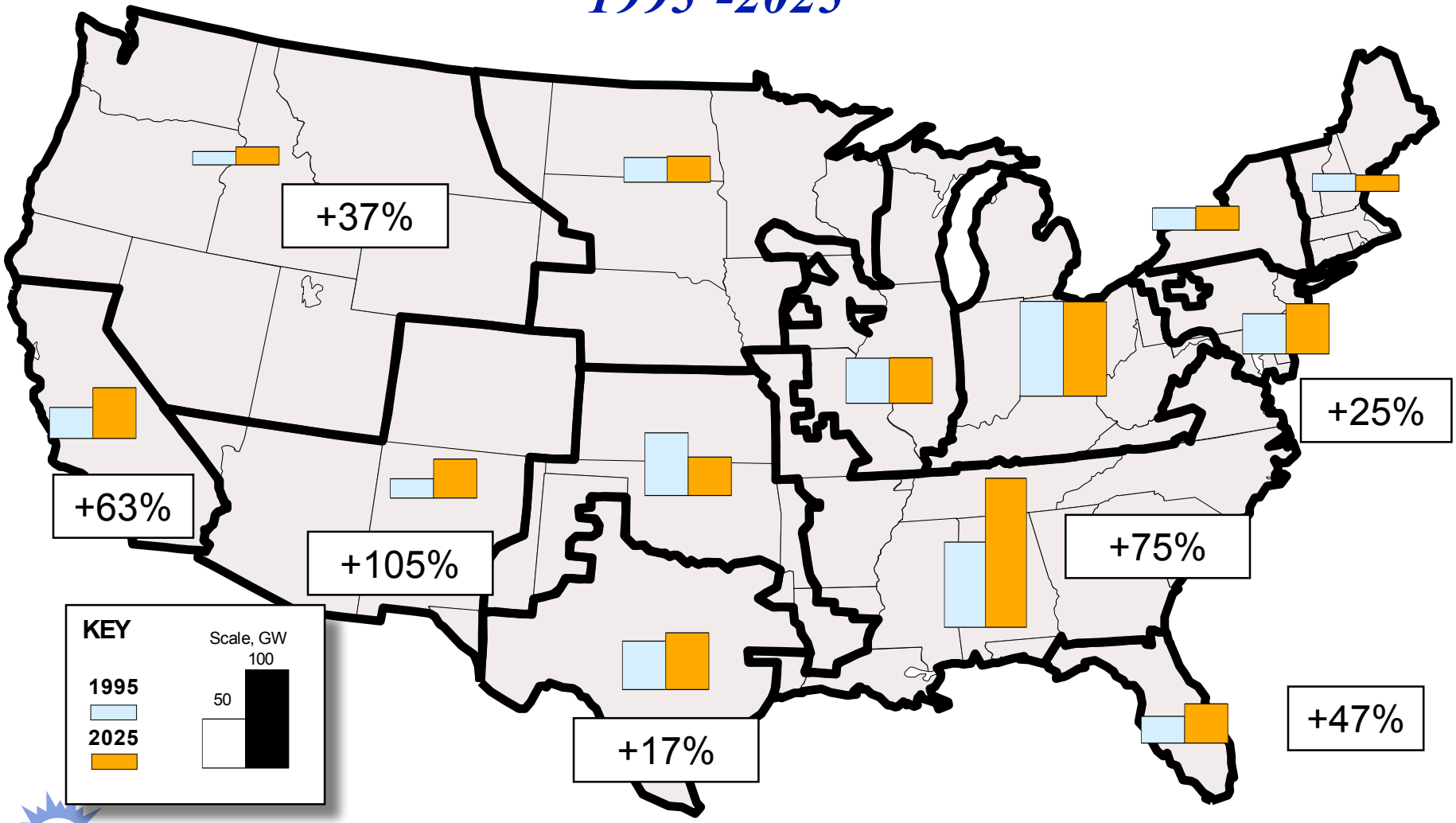
Thermoelectric Generation is Increasing

Figure 4. Electricity generation by fuel, 1970-2025 (billion kilowatthours)



Source: Energy Information Agency, AEO 2004

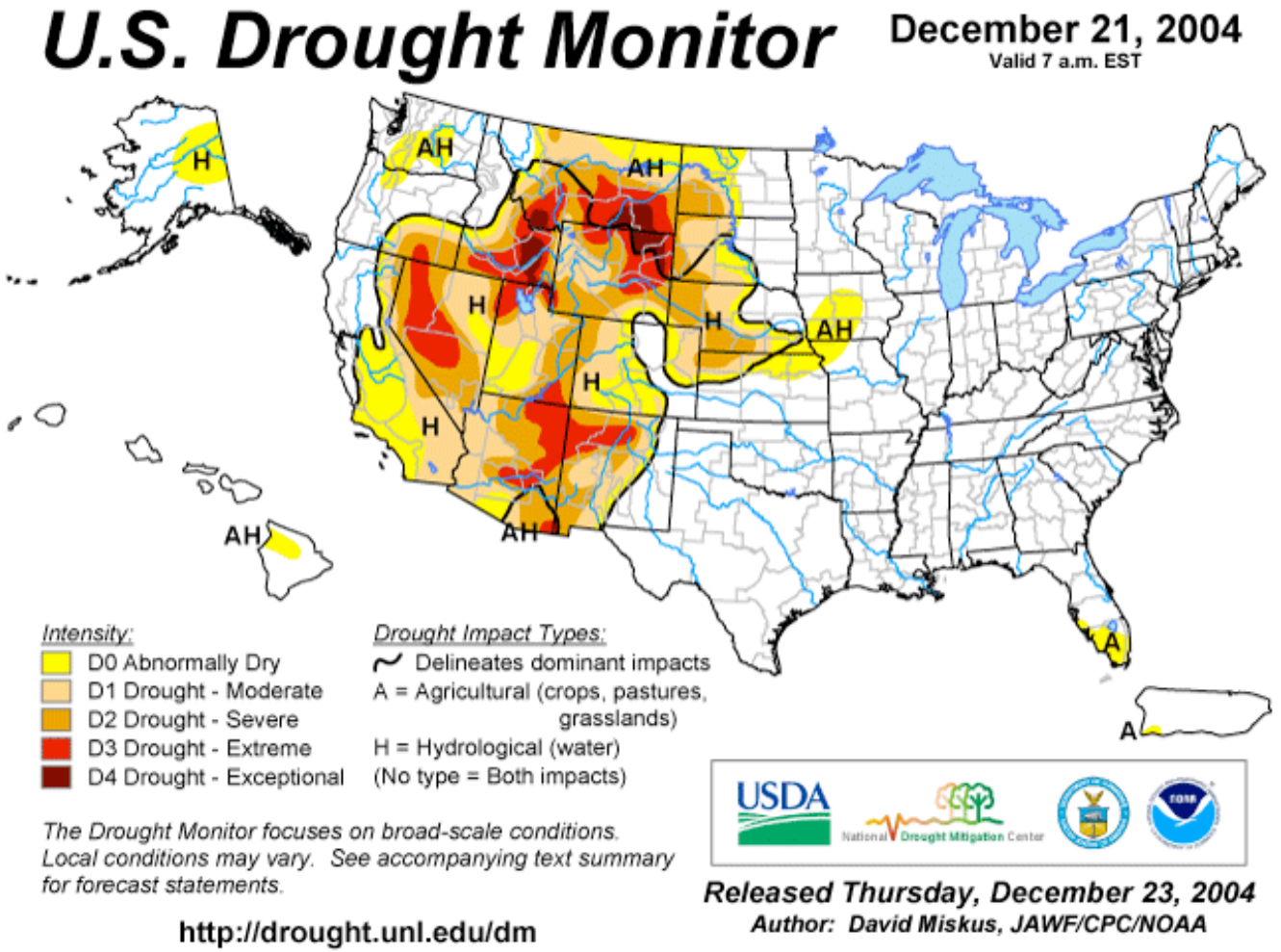
Comparison of Regional Thermoelectric[1] Generation Capacity by North American Electric Reliability Council Region, 1995[2]-2025[3]



Notes 1. For combined-cycle capacity, thermoelectric capacity is assumed 1/3 of generation capacity.
2. Source: Energy Information Agency, AEO 1997
3. Source: Energy Information Agency, AEO 2005

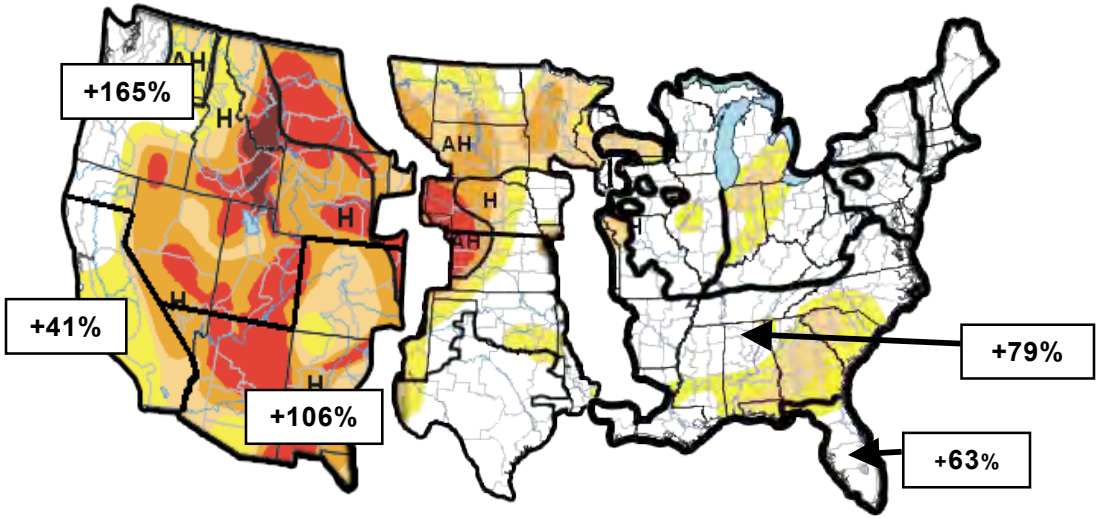
BAC 05/05

Regional Drought Conditions Exacerbate Situation



Future Analysis

- Projected regional increases in thermoelectric capacity of 41-165% in western U.S, 63-79% in southeast U.S., by 2025
- Western and southeast U.S. already facing water availability issues
- Largest increase in population also projected in these areas

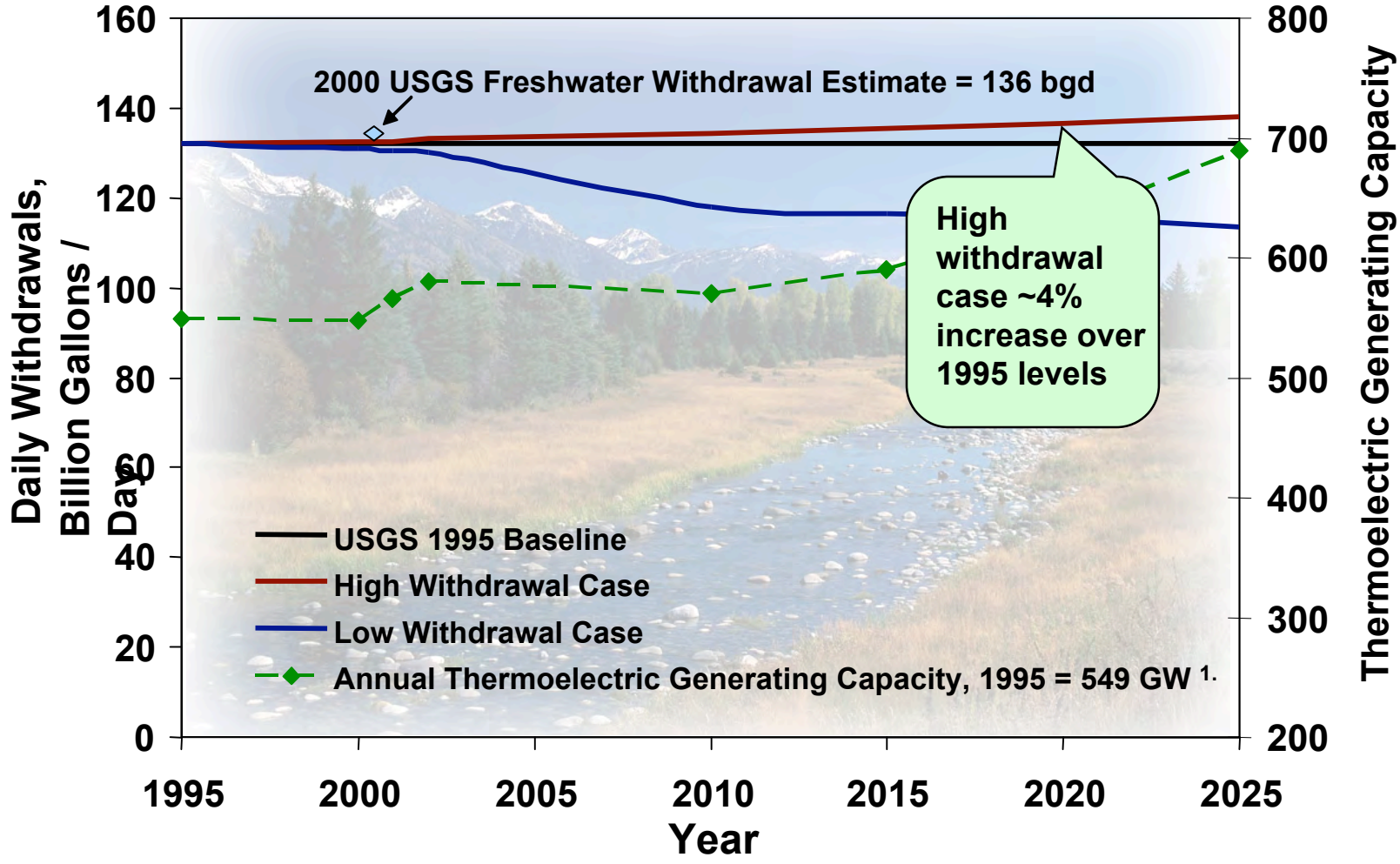


EIA projected regional thermoelectric generation growth by North American Electric Reliability Council Region

- Potential for conflict in several western cities as power generators compete with other water users

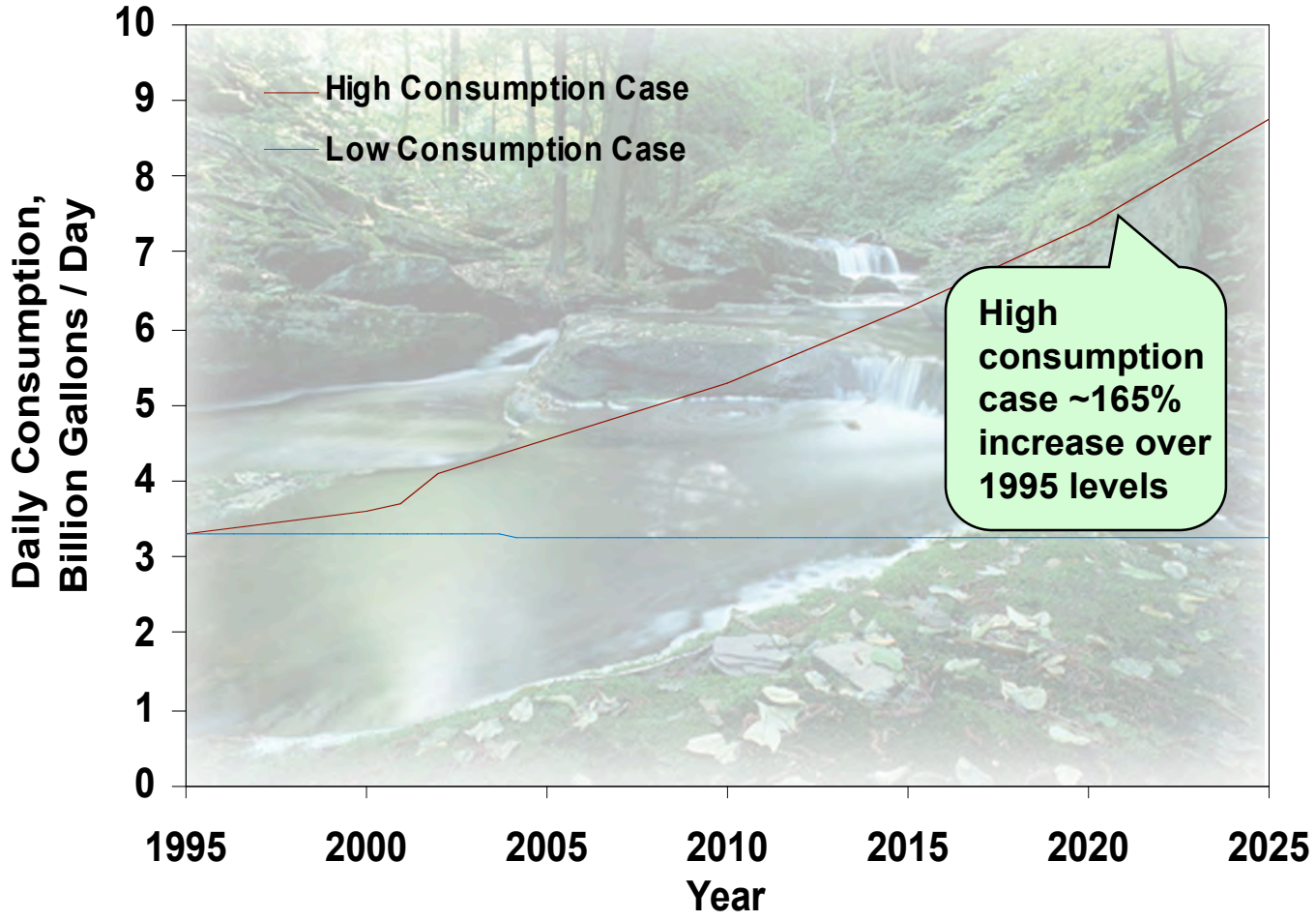
NETL kicked off a regional freshwater needs assessment in October 2004

Daily Freshwater Withdrawals Needed to Meet Forecasted Increases in Thermoelectric Capacity



Ref. DOE/NETL, "Estimating Freshwater Needs to Meet 2025 Electricity Generating Capacity Forecasts," June 2004.

Daily Freshwater Consumption Needed to Meet Forecasted Increases in Thermoelectric Capacity



Ref. DOE/NETL, "Estimating Freshwater Needs to Meet 2025 Electricity Generating Capacity Forecasts," June 2004.

Key Takeaways

- **Water will be required to meet future electricity demand**
- **On national basis freshwater withdrawals for new fossil-based generating capacity may either increase slightly or decrease through 2025, while freshwater consumption could increase significantly**
- **Water is also a regional issue:**
  - Population growth and concomitant increases in electricity demand will occur in regions that are water challenged
- **Demand for water for power will increasingly compete with other sectors such as agriculture, industrial, domestic, and in-stream use – who gets water first?**

NETL's Power Plant Water R&D Program
Research Objectives[1.]

- **Reduce withdrawal of fresh surface and/or ground water for thermoelectric power generation**
  - Reduce withdrawals and consumption by 5%-10% by 2015
- **Minimize potential impacts of power plant operations (both air emissions and effluent discharges) on water quality**

[1.] **DOE/CURC/EPRI *"Clean Coal Technology Roadmap,"* www.netl.doe.gov**

Coal Drying to Reduce Water Consumed in Pulverized Coal Power Plants

Great River Energy's Coal Creek Station, North Dakota

- Lehigh University and Great River Energy
- Previous work demonstrates coal drying can improve heat rate and reduce cooling tower makeup water requirements
- Low temperature drying of subbituminous and lignite coals through recovery of low grade waste heat from steam condenser
- Examining fluidized bed drier designs
- Small lab study progressed to Clean Coal Power Initiative $26 Million project (43%DOE funded)

NETL

"Innovative Water Management Technologies and Concepts for Coal-Fired Electric Utility Boilers"

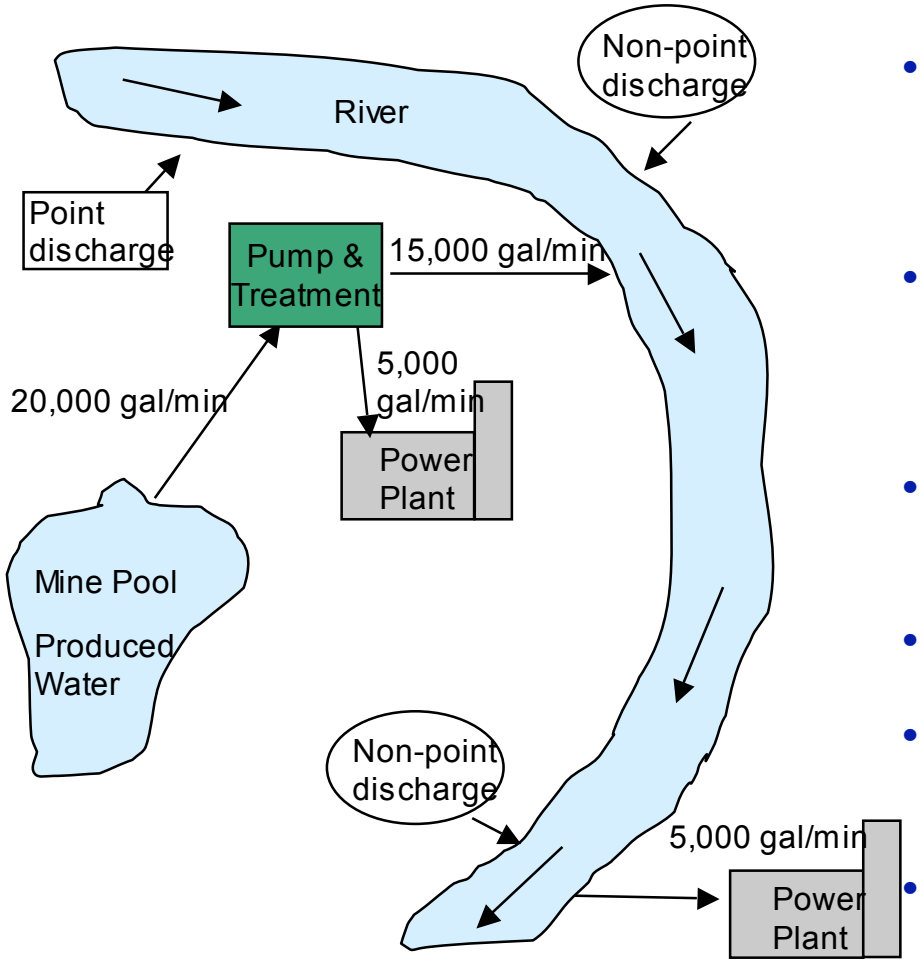
- **Targeted competitive solicitation closed February 14, 2003**
- **Four topic areas:**
  - Non-Traditional Sources of Process and Cooling Water
  - Innovative Cooling Technology
  - Advanced Cooling Water Intake Technology
  - Advanced Pollutant Measurement and Treatment Technology
- **Five projects selected**

Strategies for Cooling Electric Generating Facilities Utilizing Mine Water

- West Virginia Water Research Institute
- Evaluate use of mine water as a source of cooling water
- Investigate feasibility of using underground mines as a heat sink for cooling

Discharge from underground coal mine

Using Non-Traditional Waters Has Multiple Benefits



- Provide cooling makeup water for adjacent and downstream power plants
- Provide water to river during low flow to benefit in-stream use and biological systems
- Dilute unregulated point and non-point pollution discharges
- Control mine flooding
- Improve quality of mine pool/CBM produce waters
- Use river as a “pipeline” to transport mine water

Scenario 1: Closed-Loop Recirculating Cooling System

- Provide makeup water for a 600 MW plant equipped with a closed-loop recirculating cooling water system
- 8 sites identified where underground mine water may be sufficient to support makeup water requirements for a 600 MW plant
- Mine water is economically viable for alkaline mine water

Scenario 2: Open Loop Once-Through Cooling System

- Provide entire cooling water requirement for a 600 MW plant equipped with an open-loop "once-through" system

- One site found to be adequate for the needs of a 200 MW plant

Pennsylvania Already Using Coal Mine Water for Cooling

- Exelon Corp.'s Limerick nuclear power plant reduced water withdrawal from Delaware River using water from Schuylkill County, PA coalmine during 4-5 month trial run in summer 2003

- A number of other small generators in the anthracite region of Pennsylvania are using mine water for cooling

Limerick Nuclear Power Plant

Company Name	Plant Location	Generating Capacity (MW)	Cooling Water Source
Gilberton Power Co.	Frackville, PA	80	Unnamed mine pool
Northeastern Power Co.	McAdoo, PA	50	Siverbrook Mine
Panther Creek Generating Station	Nesquehoning, PA	83	Lausanne Mine
Schuylkill Energy Resources	Shenandoah, PA	80	Maple Hill Mine
WPS – Westwood Generation	Tremont, PA	31	Lyken Mine
Wheelabrator Frackville Energy Co.	Frackville, PA	42	Morea Mine

Use of Produced Water in Recirculated Cooling Systems at Power Generation Facilities

San Juan Generating Station

- EPRI in partnership with Public Service of New Mexico
- Evaluate use of oil/gas produced water in re-circulating cooling systems at San Juan Generating Station in NW New Mexico
- Use of Wet Surface Air Cooler with high TDS water
- Watershed Assessment Risk Analysis Framework (WARMF) applied to the San Juan River Basin (SJRB)
- Part of NM ZeroNet initiative-meet power demand with no additional water withdrawal

McGrath Salt Water Disposal (SWD) Facility

- **Impact or Benefit**
  - Water produced from oil and gas wells may provide up to 10% of the cooling water requirements of the 1800 MW San Juan Generating Station. This water source may become critical to future operation at full loads (without de-rates) in drought years

Water Volume

- 1800 MW Plant, 20 MGD water use
- 18,400 oil and gas wells in the San Juan Basin
- 2.2 MGD produced water (1.8 MGD close- in)
- Transportation is an issue
- Water quality is an issue

Water Quality

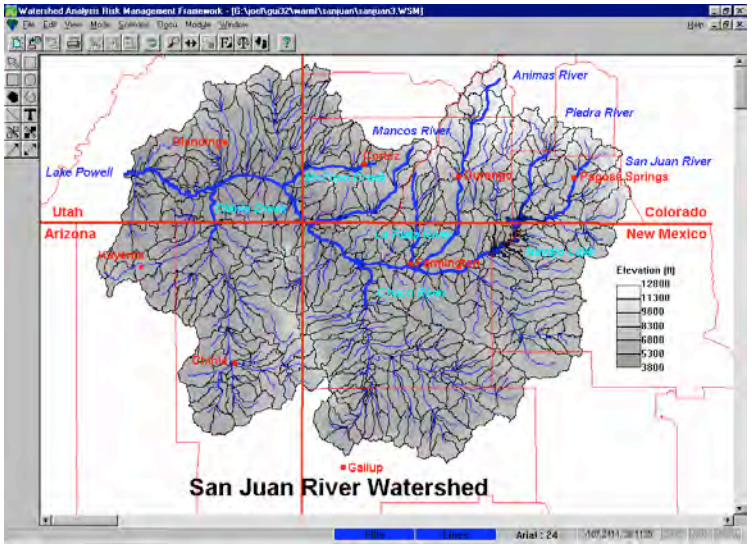
Water Source	TDS Concentration
San Juan River	360 mg/L
Produced Water	5,440 – 60,000 mg/L
Sea Water	26,000 mg/L

- **Cooling Tower Constraints**
  - Ca < 1,600 mg/L
  - Cl < 1000 mg/L
- **Treatment Technology--High Efficiency Reverse Osmosis and Brine Concentrator**

Wet Surface Air Cooler

- Auxiliary heat exchanger to cool water from the steam condensor.
- Low quality produced water can be used or blowdown from cooling towers.
- Demonstration test unit installed May 2005.

WARMF Applied to San Juan River Basin, NM

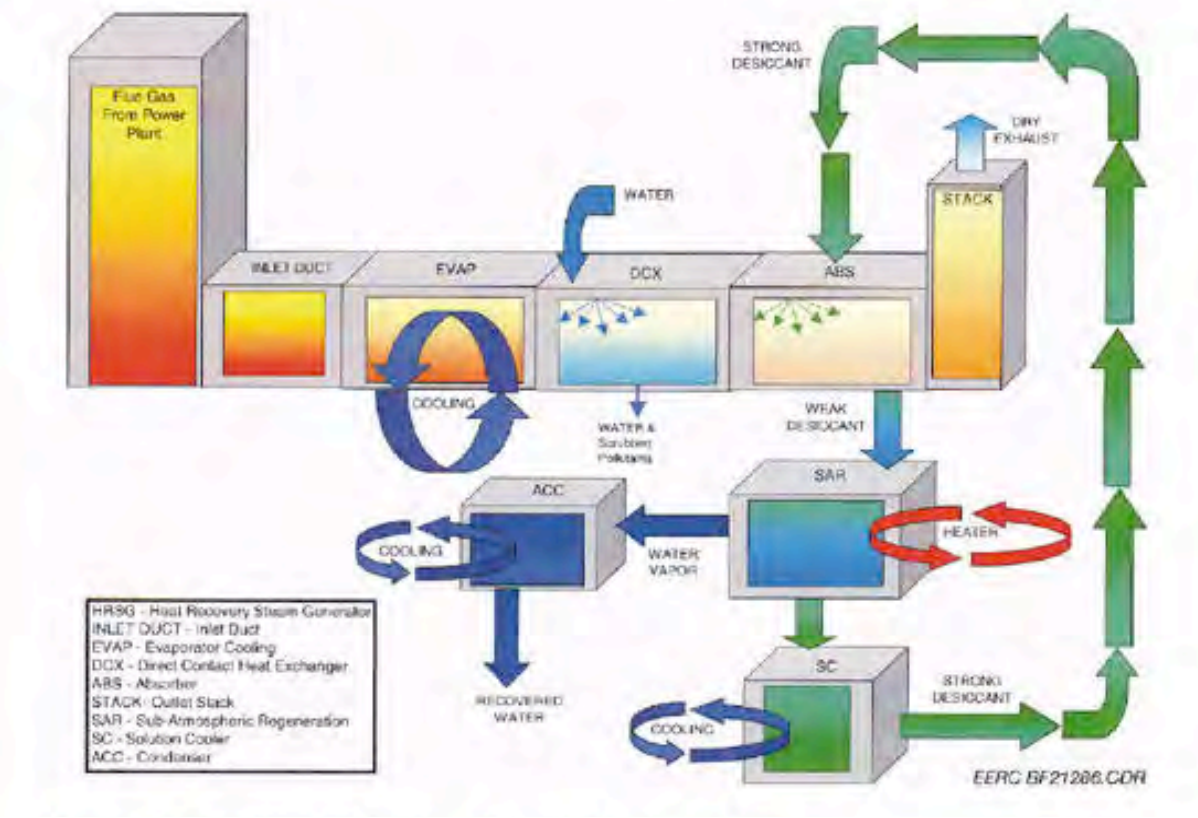


- WARMF: a decision support system for watershed management that includes a tool for TMDL calculation and a roadmap for consensus building
- Comparison of Traditional vs. Advanced Cooling
- Comparison of Water Shortage Sharing Schemes
- Empower stakeholders to make participatory decisions

Water Extraction from Coal-Fired Power Plant Flue Gas

- Energy & Environmental Research Center and Siemens Westinghouse Power Corporation
- Develop and test a desiccant-based dehumidification process that removes water from exhaust gas of fossil fuel-fired power plants

Water Extraction from Coal-Fired Power Plant Flue Gas – *UND EERC*



Flue gas dehydration technology will recover some water lost in the flue gas.

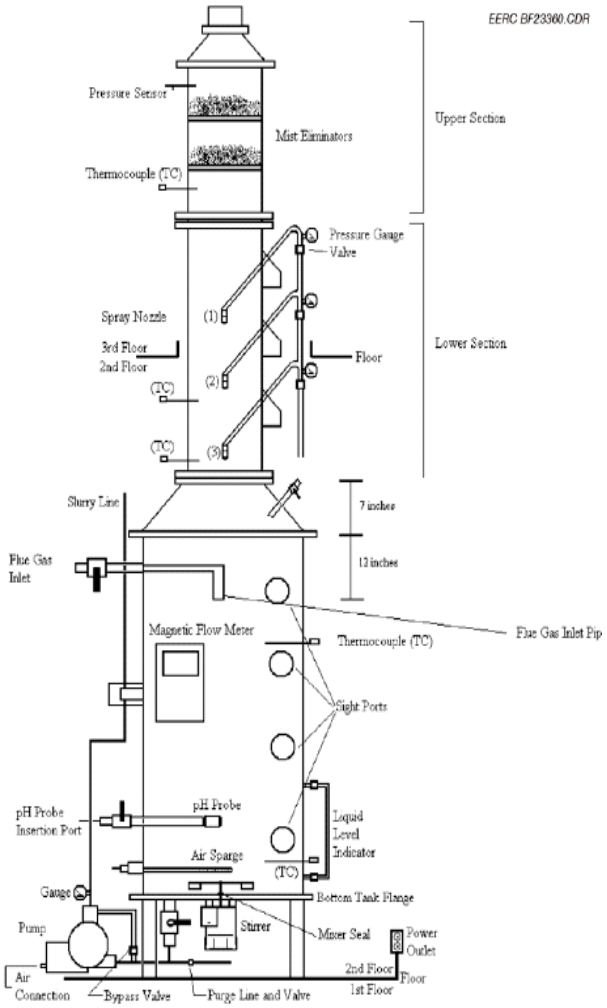


Figure 1. Schematic of the CEPS FGD system.

Task 1: Desiccant selection from literature search—Complete
3 Desiccants chosen

Task 2: Desiccant Bench Scale Test—Complete
1 Desiccant chosen

Task 3-6: Pilot test preparation-Complete

Task 7 – Pilot Testing-Complete

Pilot Scale Test

Absorber Tower

Packing material

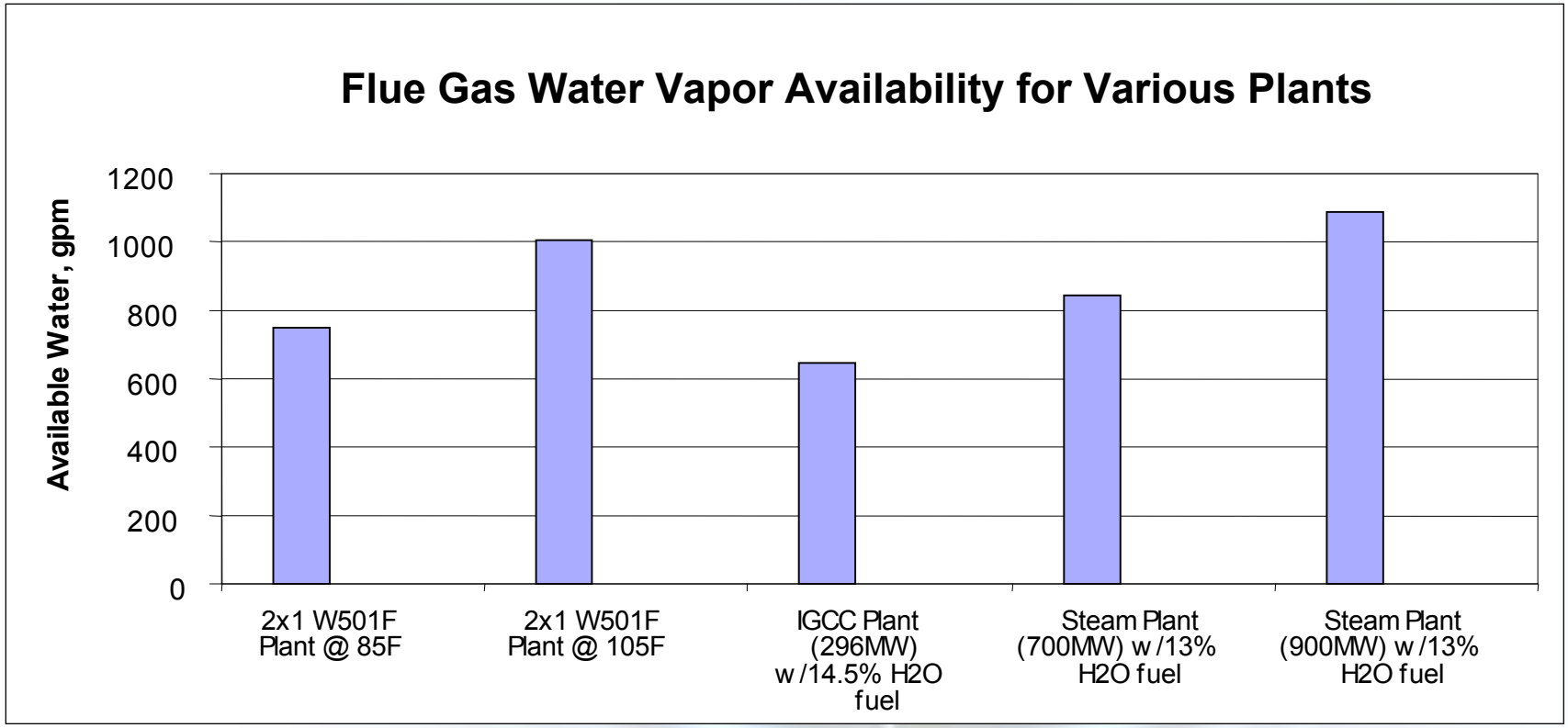
Flash Tank

Pilot Scale Test

Top of Flash Tank

Water Recovery

How Much Water is Available in Flue Gas?



- **Could provide 10%-15% of makeup water in recirculating cooling system**

Source: University of North Dakota Energy & Environmental Research Center

Results to Date

- $CaCl_2$ was selected as the desiccant from a bench-scale evaluation of three desiccants chosen from physical and chemical data.
- Pilot-scale testing show that the process works.
- Extracted water quality is excellent for natural gas-fired run, quality should be obtainable from coal.
- Patent obtained. Prospects for commercial development are encouraging.

Fate of As, Se, and Hg in a Passive Integrated System for Treatment of Fossil Plant Wastewater

- TVA and EPRI
- Evaluate passive wastewater treatment system at TVA's Paradise Fossil Plant
- Removal of nitrogen, arsenic, selenium, and mercury from fly-ash impoundments

Paradise Fossil Plant

Treatment Methods

- **Trickling Filters (ATOXIC)**

  Biological nitrification converts ammonium (NH_4) to nitrate (NH_3)

- **ZVI Extraction Trench (ASSET)**

  Trace element removal or transformation via adsorption and coprecipitation

- **Settling/Oxidation Basin (ASSET)**

  Metal hydroxide formation and collection

- **Constructed Wetland (ATOXIC)**

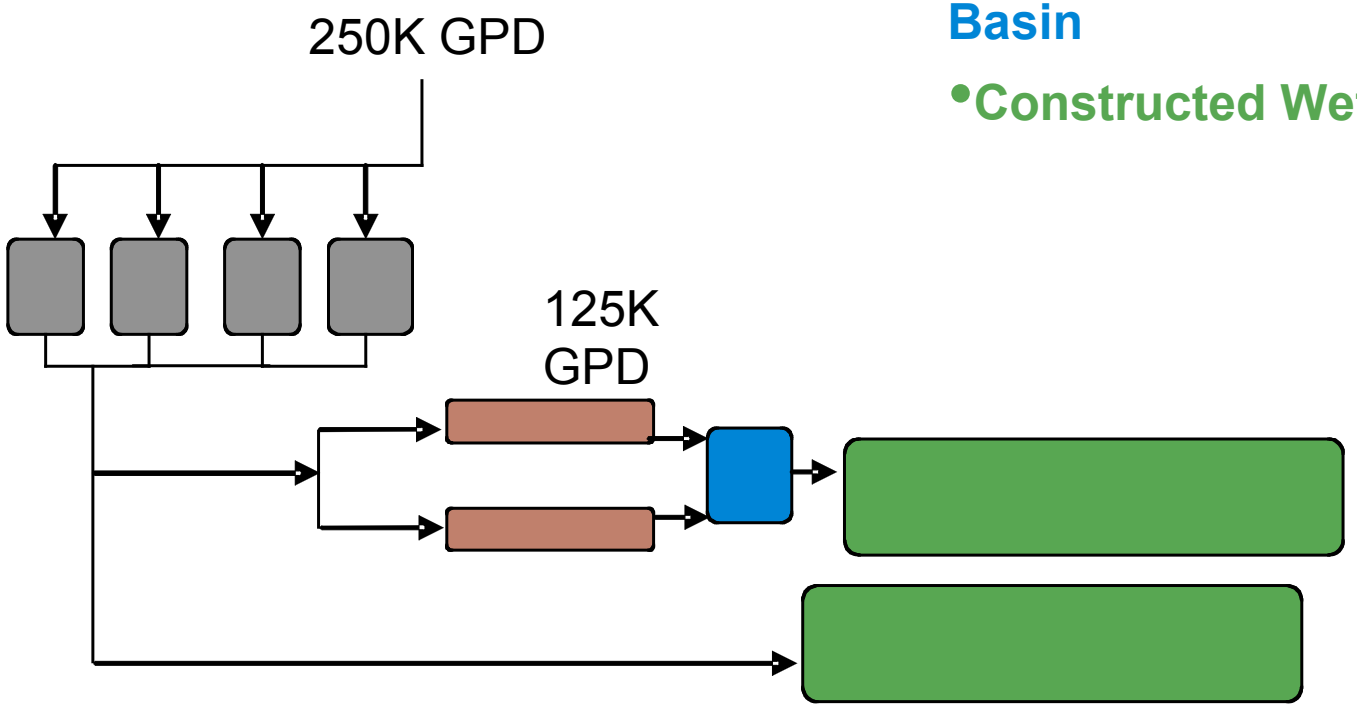
  Biological denitrification (NO_3 to N_2) and additional metals removal via sulfide precipitation

Treatment 1

- Trickling Filter
- Constructed Wetland

Treatment 2

- Trickling Filter
- ZVI Extraction Trench
- Settling/Oxidation Basin
- Constructed Wetland



Environmentally Safe Control of Zebra Mussel Fouling

Zebra Mussels

- Rochester Gas & Electric partnership with NY State Education Dept
- Evaluate innovative methods to control bio-fouling of cooling water intake systems that incorporates selective toxins from a naturally-occurring bacterium

SBIR Project

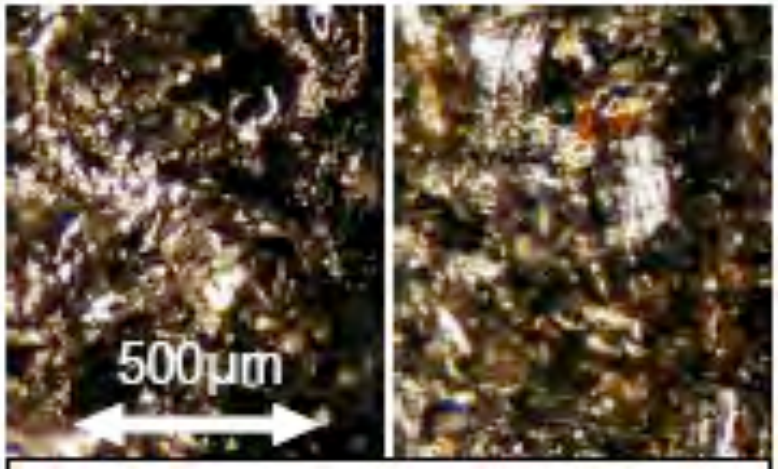
- Ceramic Composites
- Enhanced Performance Carbon Foam Heat Exchanger For Power Plant Cooling
- High Thermal Conductivity Carbon Foam
- Phase II project

Strength Enhancement

- Compressive Strength increased 2.5x
- Thermal Conductivity decreased 5%
- Friability Reduced

- Double the heat transfer of aluminum

- Cost is an issue



Silicon Carbide Polymer
Precursor Addition
Left-Before, Right-After

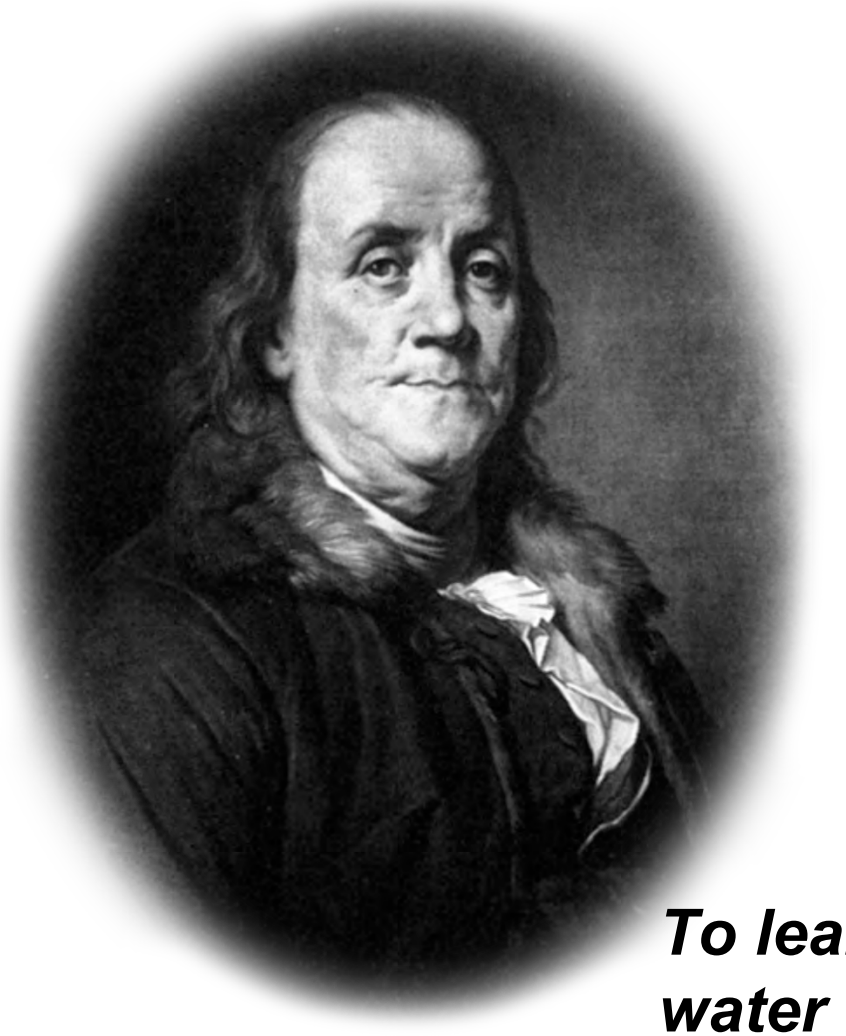
University Coal Research

- University of Florida - Diffusion Driven Desalination (DDD) process - evaporation of mineralized water within a packed bed to produce fresh water with energy from condenser of a steam power generating plant.
- Clemson University – Constructed wetlands for treatment of scrubber wastewater
- University of Southern California-Anionic Clay Adsorbents for wastewater

Current Solicitation

“ *Advanced Technologies and Concepts to Minimize Freshwater Use in Coal-Based Thermoelectric Power Plants,”* closes on June 10, 2005

- Use of Non-Traditional (Impaired) Water
- Advanced Cooling Technology
- Advanced Water Recovery and Reuse Technology
- Use of Produced Water from Carbon Sequestration



"When the well runs dry we know the worth of water."

– Benjamin Franklin

To learn more about NETL's energy-water R&D activities, please visit us at:

http://www.netl.doe.gov/coal/E&WR/index.html